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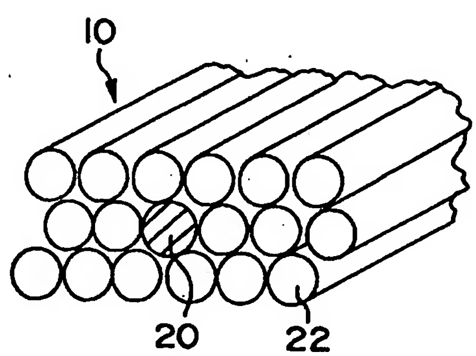

(57) Abstract

A fiber WDM coupler device which efficiently couples optical radiation into a single mode optical transmission fiber, and a method of transmitting optical radiation through a fiber WDM coupler device. The fiber WDM coupler device forms a fiber bundle having a plurality of multimode optical fibers in substantially parallel juxtaposition and a single mode optical fiber in substantially parallel juxtaposition with and substantially surrounded by the plurality of multimode optical fibers. The single mode optical fiber is coupled to a first optical radiation source transmitting laser radiation carrying data, and the multimode optical fibers are coupled to a plurality of second optical radiation sources transmitting pump laser radiation. In one embodiment, the single mode fiber is doped such that when signal laser radiation is transmitted through the single mode optical fiber, pump laser radiation energy is transferred thereto, resulting in the amplification of the signal laser radiation.

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OPTICAL FIBER BUNDLE WITH A SINGLE MODE OPTICAL FIBER SURROUNDED BY MULTI-MODE OPTICAL FIBERS AND METHOD OF MANUFACTURE THEREOF

Field of the Invention

This invention relates to an optical fiber coupler, more particularly, a wavelength division multiplexer coupler forming a fiber bundle.

Background of the Invention

Optical couplers permit optical beams to be combined. As such optical couplers have a multitude of uses. Optical couplers for example are used to multiplex optical signals in the same optical fiber in a telecommunications network and to combine signal radiation and pump radiation in an optical amplifier.

Optical couplers may be constructed as bulk optical couplers or fiber optic couplers. A conventional "bulk optic" optical coupler, known to the prior art, for example for combining signal radiation and pump radiation in an optical amplifier, is shown Fig. 1. As shown, a dichroic mirror 1 which is transmissive to the signal radiation wavelength and reflective to the pump radiation wavelength, receives an input optical data signal from signal radiation source 2 and an input pump laser beam from pump laser source 3. The data signal is transmitted through the mirror 1 and the pump beam is reflected by the mirror 1. The data signal and the pump beam are thus simultaneously combined in the gain medium 4 which amplifies the signal radiation. This amplified data signal is, for example, then transmitted into an optical fiber which is a part of an optical fiber network. Although this bulk optic optical coupler effectively combines the data signal and the pump beam, it is difficult to fabricate such a coupler so that it is compact, robust, and available at a low cost.

Within the past decade or so, optical couplers employing optical fibers have emerged. The use of the fiber optic couplers has become widespread due in part to the high degree of energy containment available within optical fibers, the good coupling properties possessed thereby, and their small size. In such a coupler as known to the prior art and, shown in Fig. 2, the cladding 5 is removed from the region 8 of each of the optical fibers 6, 7 to be joined. The cores 9 of each

optical fiber 6, 7 are fused together in the region 8. Light injected (I_1) in fiber 6 and light injected (I_2) in fiber 7 are combined in the region of coupling 8 and the combined light (O_1) may be obtained from the opposite end of one of the coupled fibers 7. Such a coupler, for example, is used to combine the signal radiation and the pump radiation for an optical amplifier.

In addition to such signal amplification in telecommunications networks, high power optical radiation is often required other applications. Broadcast cable suppliers require high power signals to reach subscribers. High speed networks require high power signals for non-linear optical switching. Medical instruments for surgery and diagnostics also require high power light beams for certain applications.

The present invention relates to a high efficiency optical coupler suitable for applications requiring amplified optical radiation.

Summary of the Invention

It is therefore an object of the invention to provide a fiber coupler device, particularly an optical fiber spatial wavelength division multiplexer coupler (hereinafter 'WDM coupler') which efficiently couples optical radiation from a laser signal radiation source and a pump laser radiation source, into an optical fiber. It is another object of this invention to provide a method of efficiently combining optical radiation from such radiation sources in a WDM coupler. In one embodiment the WDM coupler of the present invention forms a fiber bundle comprising a plurality of multimode optical fibers in parallel juxtaposition and a single mode optical fiber in substantially parallel juxtaposition with and substantially surrounded by the plurality of multimode optical fibers. The single mode optical fiber is coupled to a first optical radiation source transmitting optical radiation at a first wavelength, and the multimode optical fibers are coupled to a plurality of second optical radiation sources transmitting optical radiation at a second wavelength. In one embodiment the first and second wavelengths are the same. In another embodiment the first and second wavelengths are different.

In yet another other embodiment of the invention, the WDM coupler acts as a preamplifier to an optical amplifier. In this embodiment, a cladless single mode fiber of the WDM coupler is doped with an optically active material such that when signal radiation is transmitted therethrough it is combined with pump radiation absorbed from the surrounding cladless multimode optical

fibers. In this way energy from the pump laser radiation is transferred to the signal radiation in the single mode doped fiber, resulting in the amplification thereof.

The WDM coupler in another embodiment, acts as a coupler to a double clad fiber amplifier. In this embodiment, a double clad fiber is coupled to an output end of the WDM coupler through an optical system. The double clad fiber comprises a single mode optical fiber core surrounded by a multimode optical material. The single mode optical fiber core of the double clad optical fiber receives signal radiation from the single mode optical fiber of the WDM coupler. The multimode optical material of the double clad optical fiber receives pump radiation from the plurality of multimode optical fibers of the WDM coupler.

In another embodiment of the present invention, a method of transmitting optical radiation through an optical coupler comprises providing a plurality of multimode optical fibers in parallel juxtaposition; providing a single mode optical fiber in substantially parallel juxtaposition with and substantially surrounded by said plurality of multimode optical fibers, the single mode optical fiber and the multimode optical fibers forming a fiber bundle; transmitting optical radiation at a first wavelength through said single mode optical fiber; and transmitting optical radiation at a second wavelength through the plurality of multimode optical fibers. In one embodiment, the first wavelength and the second wavelength are the same. In another embodiment the first wavelength and the second wavelength are different.

In yet another embodiment of the invention, the method can include providing a doped cladless single mode optical fiber, transferring high power optical radiation from cladless multimode optical fibers to the cladless doped single mode optical fiber, and amplifying the signal radiation in the cladless doped single mode optical fiber. In still another embodiment of the invention, the method can include coupling an optical fiber amplifier to the fiber bundle.

These and other objects, aspects, features and advantages of the invention will become more apparent from the following drawings, detailed description and claims.

Brief Description of the Drawings

This invention is pointed out with particularity in the appended claims. The above and further advantages of this invention may be better understood by referring to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 shows a prior art bulk optic wave division multiplexer.

Fig. 2 shows a prior art fiber coupler.

Fig. 3 shows an embodiment of the WDM coupler device of the present invention including a plurality of multimode fibers encircling a single mode fiber.

Fig. 4 shows another embodiment of the fiber WDM coupler device of the present invention coupled to a double clad fiber through an optical system.

Fig. 4a shows yet another embodiment of the fiber WDM coupler device of the present invention coupled to a single mode optical amplifier through an optical system.

Fig. 4b shows an embodiment of a communication system using the WDM couplers of the invention with optical amplifiers.

Fig. 5 shows another embodiment of the present invention, particularly the WDM coupler device of the present invention used as a preamplifier.

Detailed Description of the Invention

Referring to Fig. 3, an embodiment of the WDM of the present invention is shown in which a cladded single mode optical fiber 20 is substantially surrounded by a plurality of cladded multimode optical fibers 22. The fibers 20, 22 are close packed such that the centers of the fibers 20, 22 in alternating layers are alligned.

Referring to Fig. 4, shown is an embodiment of the WDM of the present invention in which an optical system 30 is used to optically couple the WDM 10 to a double clad optical fiber 40. The double clad optical fiber 40 includes a single mode optical fiber 42 surrounded by a multimode optical material 44. The multimode optical material is in turn surrounded by cladding 45. As shown in this figure, the single mode optical fiber 20 of the WDM coupler 10 of the present invention receives laser radiation from a signal radiation source 12 through an intermediate optical fiber 13. Similarly each of the plurality of multimode optical fibers 22 receives pump radiation from a respective one of a plurality of pump laser radiation sources 14 (only one shown for clarity) through an intermediate fiber 15. In one embodiment the signal radiation source 12 emits laser radiation at a different wavelength and power than the pump laser

radiation sources 14. In another embodiment, the signal radiation source 12 emits laser radiation at the same wavelength as the pump radiation sources 14.

In one embodiment the signal radiation source 12 is a diode laser with an attached intermediate optical fiber 13. The signal radiation source emits signal radiation of a narrow spectral width. Each pump laser source 14 is preferably a semiconductor pump laser with an attached intermediate optical fiber 15. As opposed to the signal radiation source 12, the pump radiation source 13 emits_optical radiation of a broad spectral width. The signal radiation in one embodiment has a wavelength of about 1550 nm, and low power, typically within the range of 1 mW-_10 mW. The signal radiation source 12 typically transmits optical radiation which has been modulated to carry data. The pump laser radiation, in one embodiment has a wavelength within the range of 800 nm to 1480 nm, and high output power, for example 0.1 W - 5 W. In another embodiment, the signal radiation source 12 and the pump laser radiation sources 13 emit the same wavelength.

In one embodiment, Fig. 4A, the double clad fiber 40 to which the coupler of the invention is optically joined is an optical amplifier 16 comprising a single-mode rare-earth doped optical fiber 42'. The rare earth doped single mode optical fiber 42' may be doped with any appropriate rare earth including but not limited to Erbium, Ytterbium, Thulium, and Praseodymium. Such single mode optical fibers are inherently diffraction-limited. As a result, such an optical amplifier is frequently used to amplify the signals injected into it by the coupler 10. The output end 46 of the single mode fiber amplifier 16 is typically connected to an optical communication system such as a telecommunications network (not shown).

Referring to Fig. 4C, a series of optical amplifiers 16 and couplers 10 may be connected in tandem in a communications network to provide sequential amplification of a data signal.

Whether the double clad optical fiber is an optical amplifier or simply a transmission optical fiber, the optical system 30 is constructed to image the single mode optical fiber 20 of the WDM coupler 10 to the single mode optical fiber 42 or 42' of the double clad optical fiber 40 or 16; respectively. Similarly, the multimode optical fibers 22 of the optical coupler 10 are imaged to simultaneously the multimode portion 44 or 44' of the dual clad optical fiber 40 or 16, respectively. In this way, the single and multimode light from the signal 12 and pump 14 lasers, respectively, are channeled to the correct portions of the double clad optical fiber 40.

In the embodiment shown, the single mode optical fiber 20 of the WDM coupler has a diameter within the range of 3 um - 10 um and a numerical aperture (hereinafter 'NA') of about 0.1. Similarly, each of the multimode optical fibers 22 has a diameter preferably within the range of 100 um - 110 um and a NA of about 0.12. The single mode optical fiber 20 is coupled to the signal radiation source 12, and each of the multimode optical fibers 22 is coupled to a pump laser optical source 14. The purpose of the optical system 30 is generally to match the exit windows of the single mode 20 and multimode fibers 22 in the coupler 10 to the entrance windows of the single mode 42 and multimode 44 portions of the double clad optical fiber 40. With this arrangement, the WDM coupler 10 of the present invention reduces losses attendant with the coupling of the pump laser source 14 to a single mode fiber amplifier 16.

According to the "Brightness Theorem" in classical optics, a lossless optical system preserves the space-angle bandwidth product, known as the ètendue of the source. The ètendue is one measure of the number of spatial modes in an optical source. For any source, the product of the area of the emission aperture, A, and the solid angle subtended by the beam Ω, is equal to the square of the product of the number of modes, M, and the wavelength, λ. This is mathematically represented by:

$$A\Omega = (M\,\lambda)^2$$

For many sources the solid angle is well approximated by the square of the numerical aperture (NA) of the source, which is the trigonometric sine of the half angle of the beam emitted from the aperture. For signal radiation source 12, of the embodiment disclosed above, M is approximately 1. For the pump laser radiation sources 14, M is typically larger; in one embodiment 5-10. The WDM coupler 10 and optical system 30 of the present invention accomplishes the requisite ètendue matching of the laser sources 12,14 to the respective portions 42, 44 single mode fiber amplifier 16.

It should also be noted that in the embodiment shown, the cross sectional areas of the WDM coupler 10 and the double clad fiber 40 are of substantially the same shape and aspect ratio. This occurs because the number of multimode optical fibers 22 is preferably of an amount and arrangement such that the ètendue of the double clad fiber 40 is completely filled within the limits imposed by the close packed geometrical stacking of the individual multimode fibers 22.

That is, the stacking geometry is set to match that of the double clad fiber 40 to within an overall magnification factor.

Given such similarities, in one embodiment, the optical system 30 may comprise a simple two lens system for magnifying or demagnifying the image of the fibers 20, 22 of the WDM coupler 10 to overlap the relevant portions 42, 44 of the double clad fiber 40. Because the shape and aspect ratio is the same for both the WDM coupler 10 and the double clad fiber 40, in this embodiment, the lens system need not be astigmatic.

Furthermore, the coupling of the WDM coupler 10 with the optical amplifier 16 is such that the match of the single mode optical fibers 20 of the WDM coupler 40 and the single mode fiber 42 of the optical amplifier 16 need not be exact. In fact, the single mode optical fibers 20 and 42 may be mismatched as long as a portion of the signal radiation is transmitted from the single mode optical fiber 20 of the coupler 10 to the single mode optical fiber 42. However, the multimode optical fibers 22 should be matched with the multimode portion 44 of the optical amplifier 16, as closely as possible. In this way, whatever amount of signal radiation is injected into in the single mode fiber 42 portion of the optical amplifier 16 can be amplified by the pump radiation injected in the multimode portion 44 of the optical amplifier 16.

If, in addition to the shape and aspect ratio, the size of WDM coupler 10 and the dual clad optical fiber 40 match, another embodiment of the invention permits butt-coupling the WDM coupler 10 with the double clad fiber 40 (not shown) directly without an intervening optical system 30.

Fig. 5 shows an alternative embodiment of the fiber WDM coupler 110 of the present invention. In this embodiment, the WDM optical coupler 110 acts as a preamplifier to the optical amplifier 16. As similarly described in the embodiment of Fig. 4, the WDM coupler 110 comprises a plurality of cladless multimode 22 optical fibers encircling a cladless single mode fiber 120 which is rare earth doped to act as an amplifier. Pump and signal radiation are transmitted from the signal radiation source 12 and the plurality of pump laser sources 14, (only one shown for clarity) respectively, by the cladless multimode optical fibers 22 and the cladless single mode optical fiber 120, respectively. Some of the pump radiation propagating through each of the multimode fibers 22, passes through the doped single mode fiber core 120 where energy

conversion to the signal radiation takes place, leading to an increase in the output signal power in the single mode optical fiber 120.

This WDM coupler 110 is optically coupled to the optical amplifier 16, such that the signal radiation transmitted through the single mode optical fiber 120 of the fiber bundle is optically coupled to the single mode fiber of the optical amplifier. Similarly, all the multimode optical fibers 22 of the coupler are optically coupled to the multimode portion of the optical amplifier 16. The signal radiation is thus transmitted into the optical amplifier 16 having a greater amplitude than the original signal due to the preamplification of the original signal by the WDM coupler 110.

The foregoing description has been limited to specific embodiments of this invention. It will be apparent however, that variations and modifications may be made to the invention, with the attainment of some or all of the advantages of the invention. Therefore, it is the object of the appended claims to cover all such variations and modifications as come within the true spirit and scope of the present invention.

Claims

1. An optical coupler comprising:

a plurality of multimode optical fibers in parallel juxtaposition; and

a single mode optical fiber in substantially parallel juxtaposition with and substantially surrounded by said plurality of multimode optical fibers, said single mode optical fiber and said plurality of multimode optical fibers forming a fiber bundle.

2. The optical coupler of claim 1 wherein said single mode optical fiber is couplable to a first optical radiation source transmitting optical radiation at a first wavelength, and said multimode optical fibers are couplable to a plurality of second optical radiation sources transmitting optical radiation at a second wavelength.

3. The optical coupler of claim 2 wherein said first and second wavelengths are the same.

4. The optical coupler of claim 2 wherein said first and second wavelengths are different.

5. The optical coupler of claim 2 wherein the first wavelength is approximately 1550 nm.

6. The optical coupler of claim 2 wherein said second wavelength is within the range of 800 nm to 1480 nm.

7. The optical coupler of claim 2 wherein the first optical radiation source emits optical radiation having a power output in the range of 0.1 mW- 10 mW.

8. The optical coupler of claim 4 wherein the second optical radiation source emits optical radiation having a power output in the range of 0.1 W - 5 W.

9. An optical coupler preamplifier comprising:

a plurality of cladless multimode optical fibers in parallel juxtaposition;

a cladless single mode optical fiber doped with a laser creating material, said cladless single mode optical fiber in substantially parallel juxtaposition with and substantially surrounded by said plurality of cladless multimode optical fibers, said cladless single mode optical fiber and said plurality of cladless multimode optical fibers forming a fiber bundle.

10. The optical coupler preamplifier of claim 9 further comprising:

a first optical radiation source coupled to said cladless doped single mode optical fiber; and

a plurality of second optical radiation sources respectively coupled to each of said plurality of multimode optical fibers.

11. The optical coupler preamplifier of claim 9, wherein the power outputted by each of said plurality of second optical radiation sources is greater than the power outputted by said first optical radiation source.

12. The optical coupler preamplifier of claim 9 wherein said optical coupler preamplifier is optically coupled to an optical amplifier.

13. A method of transmitting optical radiation comprising:

transmitting optical radiation at a first wavelength through a single mode optical fiber; and

transmitting optical radiation at a second wavelength through a plurality of multimode optical fibers, said multimode optical fibers surrounding said single mode optical fiber and in substantially parallel juxtaposition therewith.

14. A method of transmitting optical radiation comprising:

providing a plurality of multimode optical fibers in parallel juxtaposition;

providing a single mode optical fiber in substantially parallel juxtaposition with and substantially surrounded by said plurality of multimode optical fibers, said single mode optical fiber and said multimode optical fibers forming a fiber bundle;

transmitting optical radiation at a first wavelength through said single mode optical fiber; and

transmitting optical radiation at a second wavelength through said plurality of multimode optical fibers.

15. The method of claim 14 wherein said step of providing said single mode optical fiber providing a cladless doped single mode optical fiber.

16. The method of claim 14 wherein said step of providing said plurality of multimode optical fibers comprises providing a plurality of cladless multimode optical fibers.

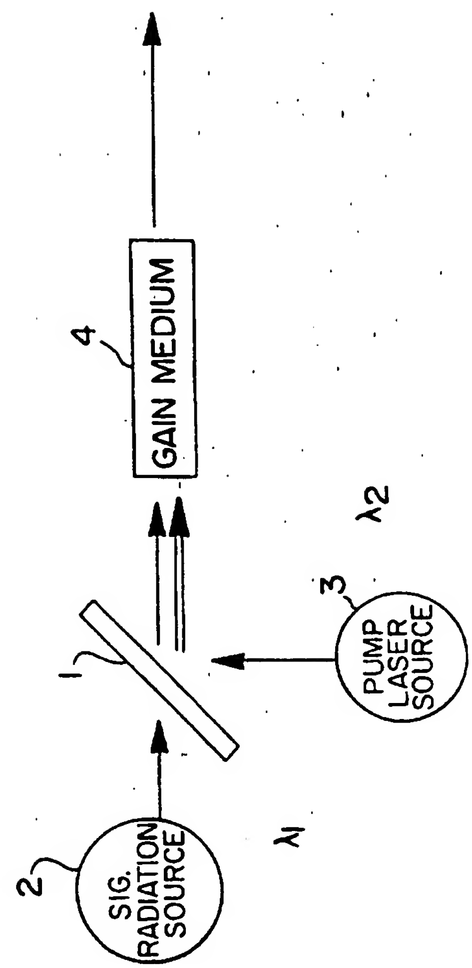


FIG. 1
PRIOR ART

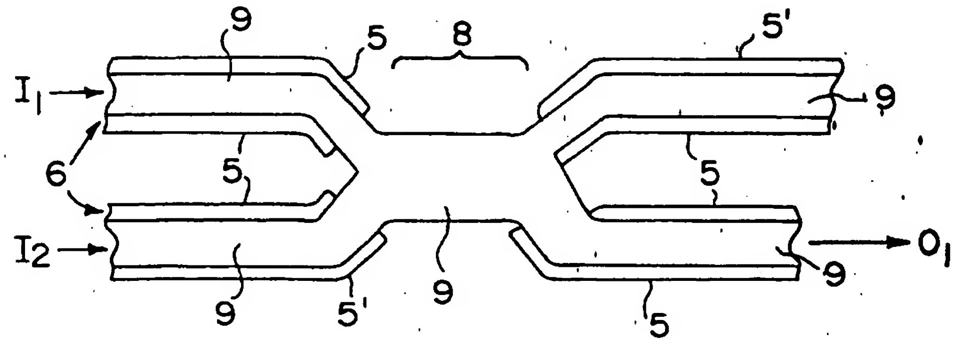


FIG. 2

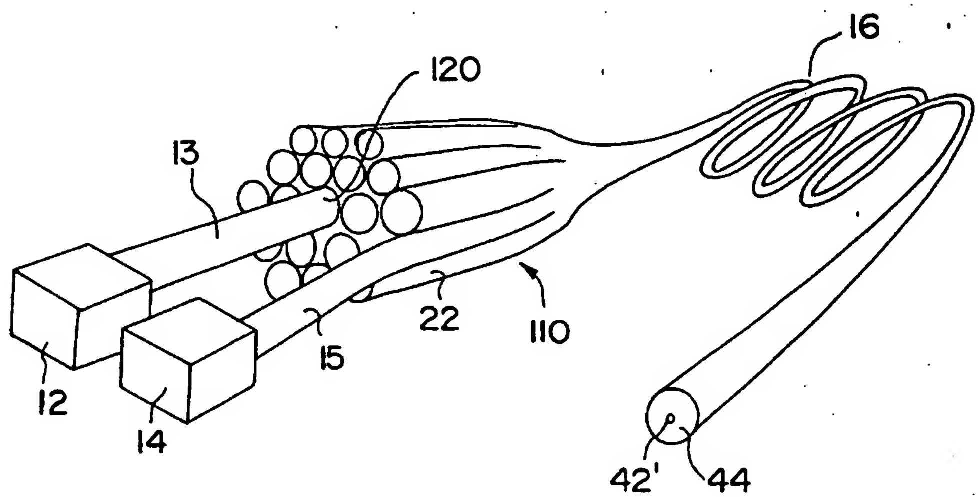


FIG. 5
PRIOR ART

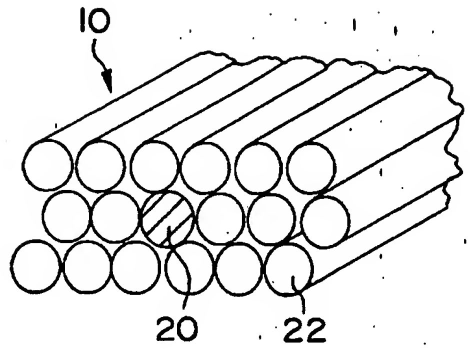


FIG. 3

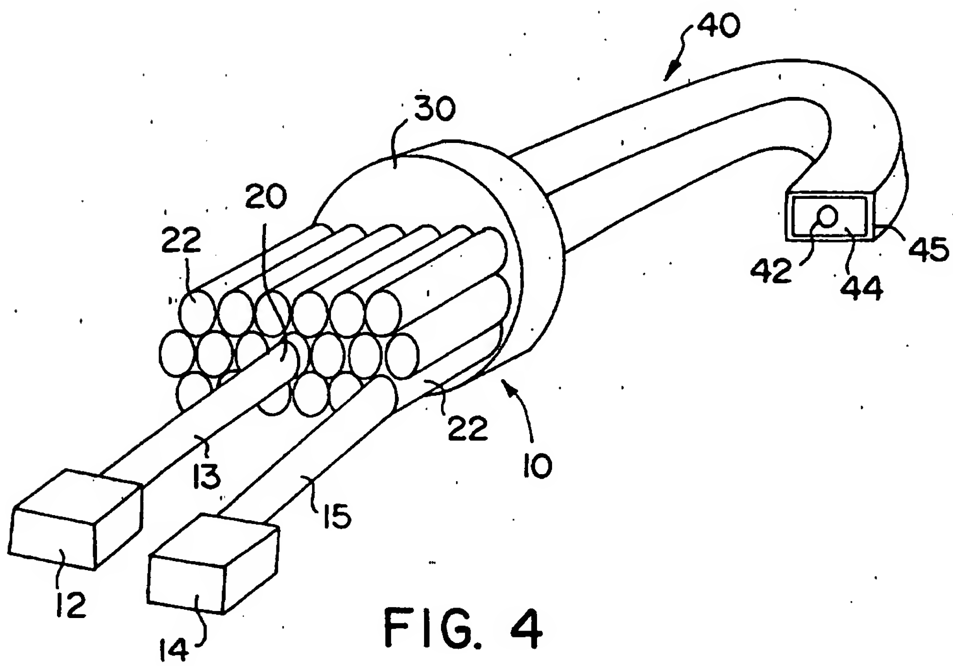


FIG. 4

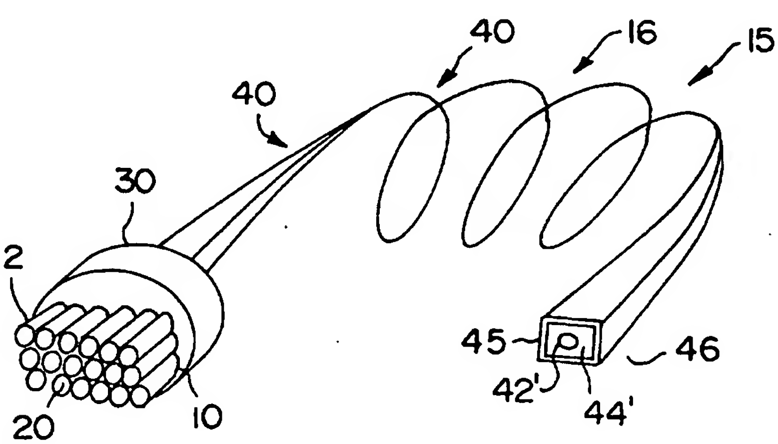
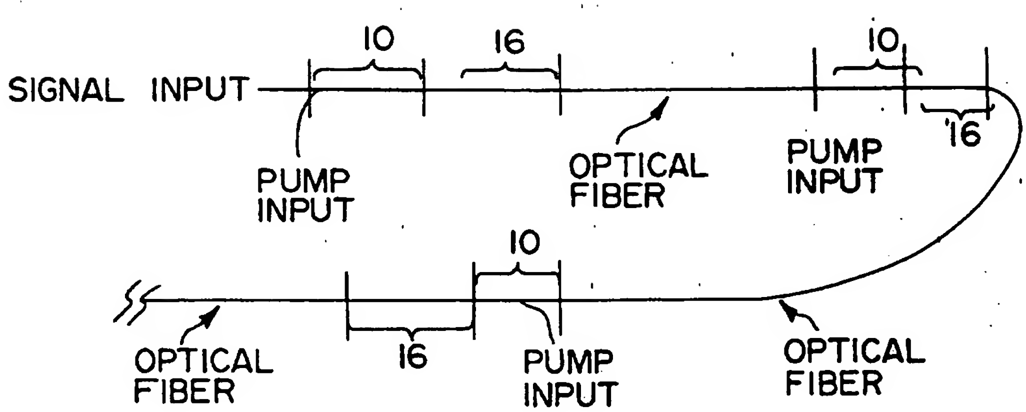


FIG. 4A



SIGNAL INPUT
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16
10
16
PUMP INPUT
OPTICAL FIBER
PUMP INPUT
10
OPTICAL FIBER
16
PUMP INPUT
OPTICAL FIBER

FIG. 4B

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/05579

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H01S3/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H01S G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 0 497 243 A (CSELT CENTRO STUDI LAB TELECOM) 5 August 1992 see abstract; figures 2-4 see column 1, line 20 - column 2, line 21 see column 3, line 7 - column 4, line 33 ---	1-4,9-16
Y	US 5 050 173 A (HUGHES JOHN L) 17 September 1991 see abstract; figures 4,5 see column 5, line 66 - column 6, line 7 ---	1-4,9-16
Y	EP 0 435 217 A (UNITED TECHNOLOGIES CORP) 3 July 1991 see abstract; figure 6 see column 5, line 43-57 ---	9-12, 14-16

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[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 July 1997	13.08.97

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 94 04365 A (ICI PLC ;HUTT KENNETH WEST (GB); ROBINSON LAURENCE JOHN (GB)) 3 March 1994 see abstract; figures 1,2 see page 6, line 27 - page 8, line 13	1-4,9-16
P,Y	WO 96 20519 A (ITALTEL SPA ;IRE POLUS CO (RU); GAPONTSEV VALENTIN P (RU); SAMARTS) 4 July 1996 see abstract; figures 3,5,7,8	1-4,9-16
Y	US 4 136 929 A (SUZAKI YASUZI) 30 January 1979 see abstract; figure 5C see column 5, line 49-68	1-4,9-16

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 97/05579

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0497243 A	05-08-92	IT 1245019 B	13-09-94
		CA 2059715 A	31-07-92
		JP 6164032 A	10-06-94
		US 5263036 A	16-11-93
US 5050173 A	17-09-91	AU 3560189 A	29-11-89
		WO 8911172 A	16-11-89
		EP 0378598 A	25-07-90
EP 0435217 A	03-07-91	DE 69026227 D	02-05-96
		DE 69026227 T	29-08-96
		JP 4127591 A	28-04-92
		US 5317576 A	31-05-94
		US 5305335 A	19-04-94
WO 9404365 A	03-03-94	DE 69306401 D	16-01-97
		DE 69306401 T	27-03-97
		EP 0656833 A	14-06-95
		JP 8501159 T	06-02-96
WO 9620519 A	04-07-96	AU 1465195 A	19-07-96
US 4136929 A	30-01-79	JP 1117518 C	15-10-82
		JP 51062743 A	31-05-76
		JP 57009041 B	19-02-82